# DISCUSSION ON "THE INVESTIGATION AND FORECASTING OF IONOSPHERIC CONDITIONS"*

## SOUTH MIDLAND RADIO GROUP, AT BIRMINGHAM, 27th APRIL, 1948

**Mr. L. G. Dive:** I believe it is correct to think of the ionosphere as a region of continuous ionization rather than as distinct layers of ionization; I should be interested to learn what is the author's opinion of the variation of ionization intensity from low to high altitudes.

I have always been rather baffled by the precise effect of the D-layer on the propagation of long-wave signals and I should welcome enlightenment in that direction.

Can the author explain the analogy of finding lower maximum usable frequencies, i.e. critical frequencies, in summer than in winter, and can he give some more information regarding the mechanism of the production of ionospheric storms, which, I believe, is due to corpuscular emission associated with sunspot activity?

**Dr. W. Wilson:** When these measurements were taken at Slough in 1935 the pulse method was used, and I should be glad if the author would give a simple description of the frequency-change method previously used. At that time, the transmitter and receiver were some little distance apart, I believe 1–2 miles. In the paper the author mentions that it is now possible to place them in close proximity, and I should be interested in information regarding the nature of the original interference.

If curve E of Fig. 1 were joined to curve $F_2$ by a vertical line, the result would be very like the upper curve in Fig. 2. Apparently the reason for the break is that curves $F_1$ and $F_2$ refer to two overlapping layers, whereas E and F do not overlap.

I am interested to learn that the ionosphere produces double refraction. What is the relation between this phenomenon and that which ordinary light goes through when passing through Iceland spar and similar crystals?

**Dr. L. G. H. Huxley:** Is the D-layer really separate, or does it only exist, as far as we know, because of the absorption, and is it thus the underskirt of the E-layer with the absorption occurring because the gas pressure is high?

During the day there is very close equilibrium between the electronic concentration and intensity of sunlight, so that as the sun shifts its angle the concentration changes accordingly. Is there some other active agent at night which maintains the residual ionization?

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* Paper by Sir Edward Appleton (see 1947, 94, Part IIIA, p. 186).

What is the order of magnitude in nepers of the attenuation of a 1-Mc/s wave incident on the ionosphere at about 60°?

**Mr. W. E. Merrill:** The author gives forecasts of maximum usable frequency for a given distance at any particular time of the day, and I wonder whether there is also a minimum usable frequency for that distance at that time of the day. I have in mind that amateurs, working on 3·5 Mc/s, seem unable to get good results during the day, whilst that particular frequency band opens up in the evening. On the other hand, they can work quite well during the day on 7 Mc/s, but it appears from the curves that at a distance of 500 km any frequency up to 10·5 Mc/s might be usable in the day-time.

**Dr. K. R. Sturley:** Fig. 1 shows that the minimum exploring frequency is 1·5 Mc/s. Does this mean that measurements have not been made below this frequency, and if this is so, how do we know that the D-layer is not another part of the E-layer, just as the F-layer appears to be split into two parts, $F_1$ and $F_2$?

Although the author refers to a splitting of the incident radio-wave into two parts, it is interesting to see that more than two reflected waves may be returned from the ionosphere. In a recent paper,* the presence of a third return ray was shown on records taken at Alaska. An explanation of this third ray, which apparently can occur only near the magnetic poles, is given in terms of the theory of magneto-ionic multiple refraction set out by Appleton and Builder.†

**Mr. D. H. Ray:** It is suggested in textbooks that some of the sky-waves travel a considerable distance through the ionized medium before returning to the ground at approximately the same distance from the sender as another wave radiated at a lower vertical angle. Has the author any confirmation that this might be so, or is it an excuse for fading at receivers which is due to interference between the two waves?

**Mr. J. A. Cooper:** The author carried out some experiments in 1924, when the aerial of the local B.B.C. transmitter, 5 I.T., was fixed between the chimneys of the Summer Lane power station. He sent out signals of varying frequency, and I think his purpose was to determine the height of the Kennelly–Heaviside layer. Some time afterwards we did some more experiments during the total eclipse of the sun, and I think the purpose was to see what happened to the height of the layer above the earth during that eclipse. I believe the author obtained the results he anticipated, and I should be interested if he would recall the work that was then done and the results obtained.

**Mr. H. G. Foster:** In his oral reply to one of the questions the author said that there was no means of filling up the gap in the electronic concentration curve between the E- and F-layers. Does he think that other means are available, and what results could we expect from rockets, for instance?

**Mr. A. E. Smith:** I believe it was stated in the Kelvin Lecture‡ of 1941 that the D-, E- and F-layers were connected with different gases; I think it was suggested that these might be ozone, oxygen and nitrogen. Also, there is a peculiar effect (and I cannot see how it could be explained) of rises in temperature at various heights, one at about 100 miles to a temperature of a little over 100° C, and, another, I believe, at the extreme limit of the gas layer to a temperature of about 1 000° C. Can the author explain this phenomenon?

**Sir Edward Appleton** (*in reply*): I will try to give an omnibus answer to these very interesting questions.

In the operation of the frequency-modulation method the sender frequency is swung continuously through a known range $\Delta f$, and the number ($\Delta n$) of interference fringes is counted. We then have

$$\frac{\Delta n}{\Delta f} = \frac{P'}{c}$$

where $P'$ is the difference of path between the atmospheric and ground waves and $c$ is the velocity of light. When the sender and receiver are close together $P'$ is, of course, equal to $2h'$. Mr. Cooper's remarks recall the period, about 1927, when he helped us by furnishing the frequency-modulated transmissions, from the Birmingham station, on which we observed at Peterborough. His assistance was of great value to us, especially in connection with the observations made during the solar eclipse of the 29th June, 1927.

Nowadays, of course, we use the pulse method of ionospheric exploration, because it facilitates the resolution of multiple echoes and lends itself readily to automatic recording. The reason for the lower limit of echo-recording on the $(h', f)$ curves given in the paper is the heavy absorption at the lower frequencies. During the day-time we have failed to detect reflections on 1 Mc/s, but I should estimate that the attenuation of such waves, at vertical incidence, would be of the order of 16 nepers, in summer day-time.

We are unable, using vertical-incidence radio sounding, to get much information about the state of ionization between the E- and F-layers; and the method can give no information about ionization at a higher level than the F-layer, owing to the inferior electron concentration. But already rocket experiments give great promise of supplementing the radio evidence in these respects.

I believe that the D-layer must be regarded as a separate stratum and not as the lower fringe of the E-layer. With very long waves, true reflection takes place from the lower boundary of the D-layer. For higher frequencies, which are refracted at higher levels, the D-layer acts as the main absorbing medium. Because of this absorption, which is mainly evident during the day-time, there is always a minimum usable frequency for any long-distance radiocommunication circuit, which is determined not only by the D-layer characteristics but also by the terminal equipment (sender power, receiver sensitivity, etc.).

The fact that day-time $F_2$-layer ionization is less in local summer than in local winter still remains unexplained. The old suggestion, that this is due to a seasonal difference of temperature, is now seen to be untenable. However, it would appear that the upper part of the ionosphere is constantly at a fairly high temperature, since it is difficult, otherwise, to explain why there should be so many air molecules at such elevated levels.

During the day-time, the ionization in the E-layer remains close to the equilibrium value, determined by the incidence of solar photons and the electron dissipation process. At night the ionization in the normal E-layer sinks rapidly to low values, because of the high rate of recombination; there is, however, some additional irregular ionizing agency, possibly meteoric dust, which prevents it from sinking still lower.

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* SEATON, S. L.: "Magnetoionic Multiple Refraction at High Latitudes," *Proceedings of the Institute of Radio Engineers*, 1948, 36, p. 450.

† APPLETON, E. V., and BUILDER, G.: "The Ionosphere as a Doubly Refracting Medium," *Proceedings of the Physical Society*, 1933, 45, p. 208.

‡ CHAPMAN, S.: "The Sun and the Ionosphere," *Journal I.E.E.*, 1941, 88, Part I, p. 400.